

## RISC-KIT: Resilience-increasing Strategies for Coasts

Ap van Dongeren<sup>1,a</sup>, Paolo Ciavola<sup>2</sup>, Grit Martinez<sup>3</sup>, Christophe Viavattene<sup>4</sup>, Simone DeKleermaeker<sup>1</sup>, Oscar Ferreira<sup>5</sup>, Cristina Costa<sup>6</sup>, Robert McCall<sup>1</sup>

<sup>1</sup> Deltares, Delft, Netherlands

<sup>2</sup> CFR, Ferrara, Italy

<sup>3</sup> Ecologic, Berlin, Germany

<sup>4</sup> Middlesex University, London, UK

<sup>5</sup> U. Algarve, Faro, Portugal

<sup>6</sup> Eurocean Lisbon, Portugal

**Abstract.** High-impact storm events have demonstrated the vulnerability of coastal zones in Europe and beyond. These impacts are likely to increase due to predicted climate change and ongoing coastal development. In order to reduce impacts, disaster risk reduction (DRR) measures need to be taken, which prevent or mitigate the effects of storm events. To drive the DRR agenda, the UNISDR formulated the Sendai Framework for Action, and the EU has issued the Floods Directive. However, neither is specific about the methods to be used to develop actionable DRR measures in the coastal zone. Therefore, there is a need to develop methods, tools and approaches which make it possible to: identify and prioritize the coastal zones which are most at risk through a Coastal Risk Assessment Framework, and to evaluate the effectiveness of DRR options for these coastal areas, using an Early Warning/Decision Support System, which can be used both in the planning and event-phase. This paper gives an overview of the products and results obtained in the FP7-funded project RISC-KIT, which aims to develop and apply a set of tools with which highly-vulnerable coastal areas (so-called “hotspots”) can be identified.

### 1 Introduction

High-impact storm events - such as the 2010 Xynthia storm in France, the 2013 Xavier/St. Nicholas storm in NW Europe and the 2014 St. Agatha storm in the Adriatic, to name a few - have demonstrated the vulnerability of coastal zones in Europe.

These risks are likely to increase due to two effects: due to predicted climate change the *hazards* of sea level rise and flooding may increase, and due to ongoing coastal development the exposure and the vulnerability (together the *consequences*) could increase.

With this view of the future, coastal authorities need to assess the level of impact and the risk of their coastal zones, and take *Disaster Risk Reduction (DRR)* measures if the safety level is not adequate. DRR measures typically fall into three categories:

- *prevention*, in which the impact is avoided altogether, for example by building dikes.
- *mitigation*, in which the impact is reduced, for example by creating marsh lands or elevating houses
- *preparedness*, by which authorities and population are trained to react to an impending storm, for example through Early Warning Systems.

To facilitate risk reduction, the UNISDR formulated the Sendai Framework for Action, and the EU has issued the Floods Directive. Under these frameworks, specific methods for developing actionable DRR measures in coastal zones should be developed, in order to guide cost-effective disaster risk prevention and management. But in order to reach that goal, a number of questions need to be addressed:

- *Where* on the coast are areas of higher risk?
- *What* is the impact of future coastal hazard scenarios?
- *What* are effective DRR measures at a hotspot?
- *How* can DRR measures best be implemented?

The RISC-KIT project aims to develop methods, tools and approaches contained in a toolkit which will help answer these questions.

### 2 The RISC-KIT toolkit

RISC-KIT is an EU-funded project with 17 partners across Europe and coordinated by Deltares, The Netherlands, and a budget of 7.6 Million Euro (6 Million Euro EC contribution). More information can be found on [www.risckit.eu](http://www.risckit.eu). The RISC-KIT toolkit will be

<sup>a</sup> Corresponding author: [Ap.vanDongeren@deltares.nl](mailto:Ap.vanDongeren@deltares.nl)

publically available, either free-ware or open-source form and comprises the following four tools:

## 2.1 Coastal Risk Assessment Framework (CRAF)

The Coastal Risk Assessment Framework or CRAF is designed to answer where the areas of increased risk (so-called hotspots) are located on a particular coast. The CRAF takes a two-step approach to select the hotspots (Figure 1).

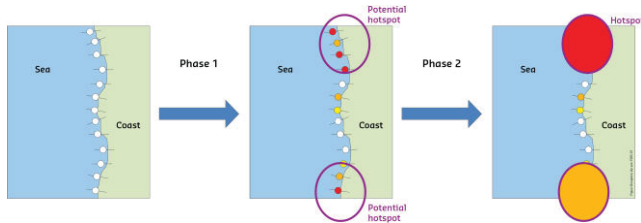


Figure 1. Schematic of the two phases of the CRAF application. Left: a plan view of the coast with transects (white dots). Middle: the result of Phase 1 where potential hotspots of high exposure are identified. Right: the result of Phase 2 where two hotspots with highest risk are identified.

In the first phase, sectors along the coast with a high potential exposure are determined, for different hazard indicators (e.g. wave overtopping, flooding and shoreline erosion) and exposure indicators (e.g. land use, social, transport, utilities and economic activities) in the form of a coastal exposure index.

Specifically, for each hazard and for one return-period, an index is calculated per sector of one-kilometre average length using the square root of the geometric mean of the hazard indicator ( $i_h$ ) and the overall exposure indicator ( $i_{exp}$ ):

$$CI = [(i_h * i_{exp})]^{1/2}$$

The hazard indicator is ranked from 0 to 5 based on the hazard intensity (None, Very Low, Low, Medium, High and Very High). An example of the erosion indicator for the case study site of Ria Formosa, Algarve, Portugal is given in Figure 2.

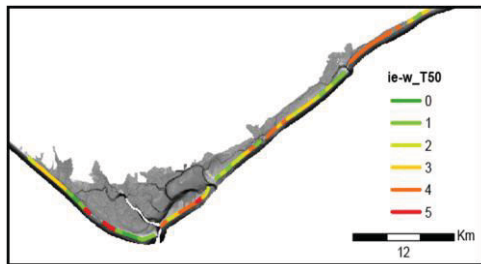


Figure 2. Erosion indicator for a return period of 1/50 per year for the case of Ria Formosa, Portugal.

The overall exposure indicator is ranked from 1 to 5 and is the result of the consideration of five specific exposure indicators calculated as:

$$i_{exp} = [(i_{exp-LU} * i_{exp-SVI} * i_{exp-TS} * i_{exp-UT} * i_{exp-BS})]^{1/5}$$

Here, the land use indicator measures the relative exposure of land use, valued by its importance. The social indicator considers the relative vulnerability of communities. The transport, utilities and businesses indicators represent the systemic significance of the exposed assets. This calculation of this exposure indicator yields a limited number of sectors along the coast with an increased exposure, which are explored in the second phase.

In the second phase, an analysis is performed using more advanced hazard and impact assessment models. Specifically, the considered hazards for the selected return-period storm are modeled using a 1D, process-based, multi-hazard model (XBeach 1D, Roelvink et al. 2009) and, if necessary, a simple 2D flood model.

The storm impacts are assessed at the regional scale using the INDRA (INtegrated DisRUption Assessment) model, i.e. household displacement, household financial recovery, regional business disruption, business financial recovery, ecosystem recovery, risk to life, regional utilities service disruption, regional transport disruption.

The hotspots are scored and ranked using a Multi-Criteria Analysis. In consultation with stakeholders, the hotspot(s) are selected using complementary information (e.g. visualization maps, data quality, etc.). The flexibility of the tool allows tailoring the comparative analysis to these different contexts and to adapt it to the quality of resources and data available. The Phase 2 analysis will yield the identification of the most critical hotspots based on current and future climate scenarios.

## 2.2 Hot spot tools

In a selected hotspot, we would like to achieve a two-fold aim. First, we intend to increase coastal resilience by developing a Coastal Flood Early Warning System at the case study sites. To this end, we have extended use of the Delft-FEWS (Flood Early Warning System, originally developed for river flooding application) for coasts so that it is now possible to make real-time surge, wave, coastal erosion and flooding predictions. The schematic in Figure 3 shows the data imports, the hydrodynamic and morphodynamic models which are used to transform inputs into water level, wave and morphological predictions, which are reported and visualized on the right.

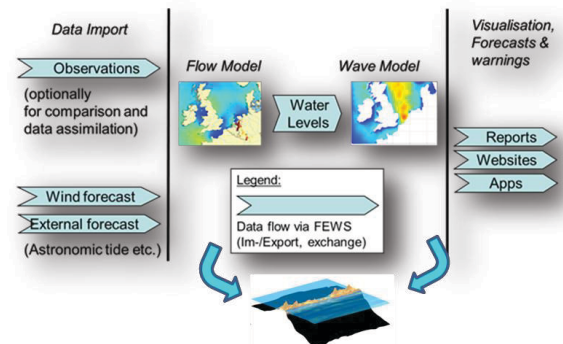


Figure 3. Schematic of Coastal Flood Early Warning System. Data imports are shown on the left. The hydro- and

morphodynamic models are shown in the middle panel and the visualisation and reporting output is shown on the right.

At the moment, the following hydro- and morphodynamic models are supported: the wave action models WaveWatch III (Tolman, 2009), SWAN (Booij et al. 1999), the tidal and surge models Delft3D (Lesser et al., 2004) and Selfe (Zhang and Baptista, 2008), Telemac (Galland et al., 1991) and the flooding model Lisflood (Bates, 2010).

For example, for the case study site of Ria Formosa a cascade of three coupled surge-wave models is made (Plomaritis, 2016, pers. Comm.), as shown in Figure 4.

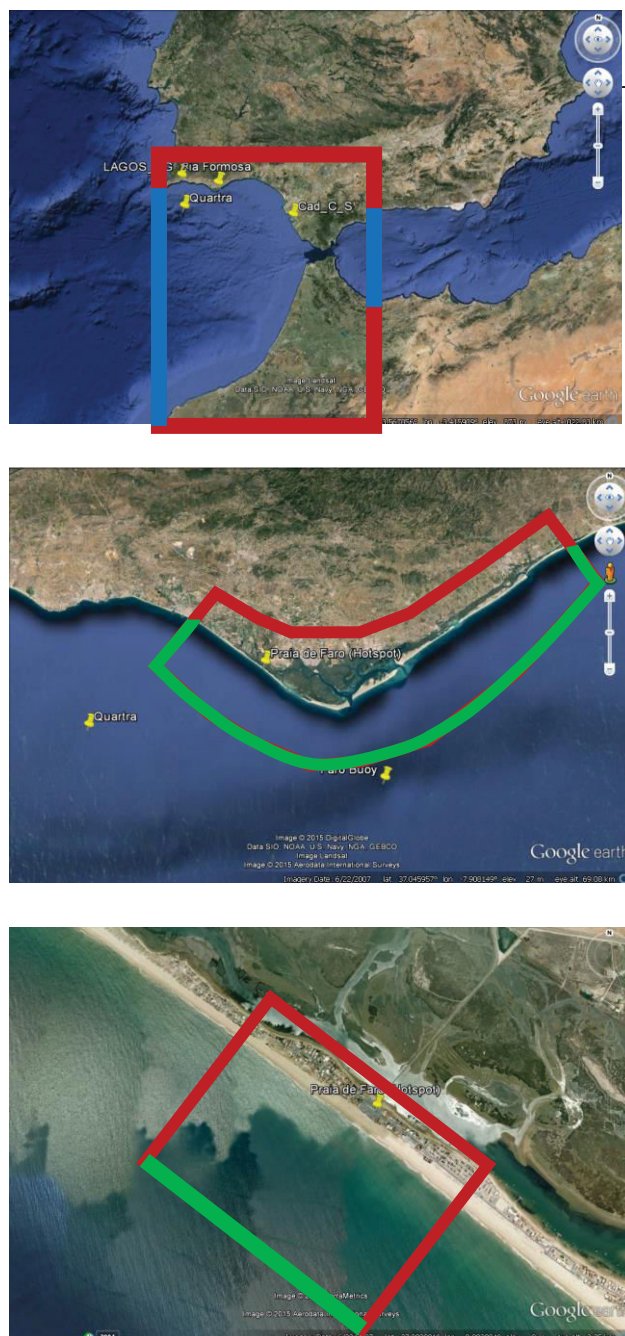


Figure 4. Cascade of nested surge, wave and morphological models. Top: regional Delft3D and SWAN model, Middle: Nested Ria Formosa Delft3D and SWAN model, and Bottom: detailed XBeach morphodynamical model. Figures courtesy H. Plomaritis and O. Ferreira, U. Algarve.

In the FEWS system, these models can be visualized as well, as shown in Figure 5:

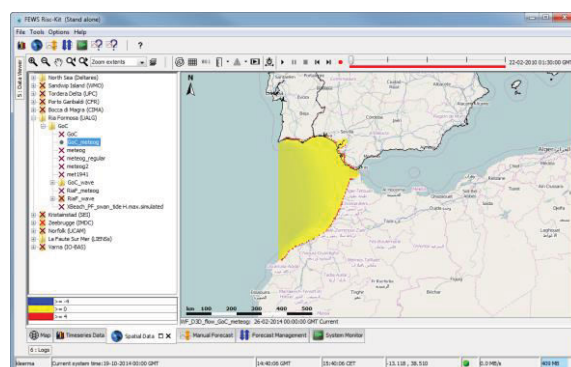


Figure 5. RISC-KIT FEWS webviewer for the Ria Formosa (Portugal) case study site.

Second, we would like to be able to accurately simulate and evaluate the effectiveness of DRR measures under storm conditions. This is achieved by the simulation of historical and climate-change related storm scenarios with and without DRR measures in place. From these simulations we obtain predictions of local flooding and erosion, which we combine with characteristics of the local population, built environment and infrastructure, to compute storm impact and the effectiveness of the measures. The results are stored in a so-called Bayesian-based Decision Support System (DSS) (Jaeger et al., 2015) which visualizes the relation between hazards, impacts and DRR measures, and gives an end-user insight in how a change in either of these components of risk affect the others.

An example for the Ria Formosa (Figure 6) case shows the structure of the Bayesian nodes relates the offshore boundary conditions (waves, tides and surge) to the local hazard intensities on shore (erosion, overwash) and the local characteristics (Poelhekke et al., 2016, in prep).

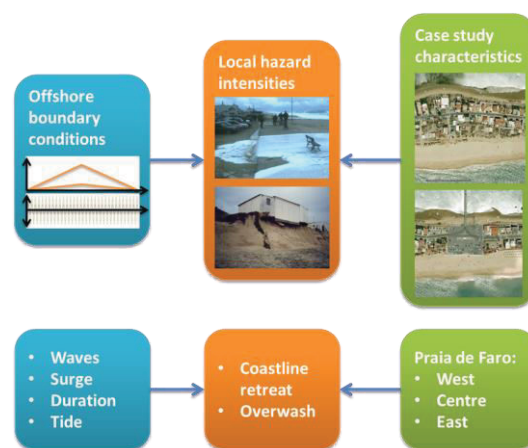


Figure 6. Relation between offshore boundary conditions, local hazard intensities and the case study site characteristics.



## 2.3 Web-based management guide

Furthermore, we developed a web-based management guide to facilitate EU-wide learning and exchange for the development of DRR measures, and will help answer the questions of what are effective measures and how they can be implemented.

The guide highlights key principles recommended for the implementation of local DRR measures using examples from the case studies and elsewhere to provide practical illustrations.

It is intended to give guidance to coastal managers in Europe and those facing similar challenges beyond the region as well as other groups concerned with coastal management (i.e. coastal resource users, technical and scientific experts and policy makers). The guide will include prevention, mitigation and preparedness measures with recommendations for their use in various socio-economic, cultural and environmental settings. It will make recommendations about cost-effectiveness and the value of ecosystem services, distinguish realistic and effective strategies, provide methods for local stakeholder involvement and make recommendations about the development of timelines for decision-making. This web-based management guide will be published in the form of an open-access webpage and will form the policy and management component of the RISC-KIT toolkit.

## 2.4 Storm Impact Database

In the Storm Impact Database, we collected (meta) data of the impact of historical storms (surges, winds, flash floods) in the case study areas. The data base includes not only physical but also socio-economic, cultural and environmental information.

A WEB-GIS interface (Figure 7) has been developed to upload impact-oriented event data at each of the RISC-KIT case study sites. Guests to the website (i.e. coastal managers, decision makers etc.) can subsequently use the event visualisation interface to filter, view and export any relevant information as desired.

In our view, the database will strengthen the efforts of local communities and national governments to apply the Floods Directive, raise historical awareness of what has occurred, and lead to a better understanding of the stakes and vulnerabilities of the case study sites in a long-term perspective. Within the project, the database is a source of validation data to test the effectiveness of DRR scenarios.

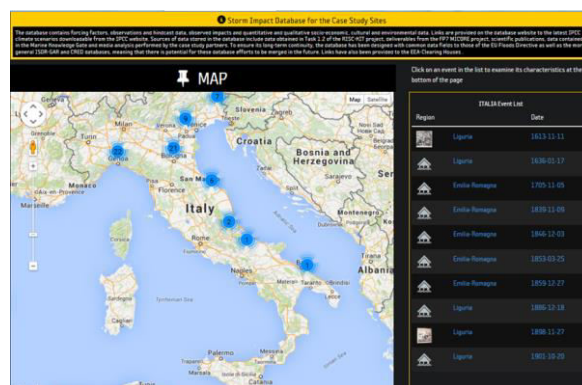


Figure 7. Storm Impact Database, identifying data collected in Italy.

The database contains not only references to physical data but also photographs of recent events. Figure 8 shows pictures taken during the St. Agatha event of February 5, 2015.



Figure 8. Photographs taken during and after the St. Agatha event in Emilia-Romagna on 5 February 2015. Photos courtesy dr. Paolo Ciavola, U. Ferrara.

This Storm Impact Database is available at <http://riskit.cloudapp.net/riskit/#/>

## 3 Application to case study sites

The developed tools have been applied to a number of case study sites, which are located on each of Europe's regional seas and one international site in Bangladesh (see Figure 9). These case study sites all exhibit different geomorphologies and environmental conditions, and range from open to closed coasts, from sandy to estuarine coasts, and from natural to urbanized and industrialized.



Figure 9. Map of Europe indicating the ten case study sites with an insert of Bangladesh indicating the location of Sandwip Island.

## 4 Impact

The project will contribute directly to the following goals.

### 4.1 Faster attainment of the DRR goals of UNISDR

RISC-KIT contributes directly to the DRR goals of the UNISDR, summarised in five Priorities for Action (PfA).

- PfA1: Ensure that disaster risk reduction is a national and local priority with a strong institutional basis for implementation; RISC-KIT provides DRR methods, tools and approaches that are applicable across the EU and beyond. When used by local governments, RISC-KIT helps to decentralise resources and responsibilities.
- PfA 2: Identify, assess and monitor disaster risks – and enhance early warning; The collection of local socio-economic and physical data into an impact-oriented coastal risk database allows for data sharing. The CRAF and EWS/DSS enables regional authorities to identify and assess multi-hazards and their impacts.
- PfA3: Use knowledge, innovation, and education to build a culture of safety and resilience at all levels; The CRAF and the impact-oriented coastal risk database will integrate hazard data and vulnerability information and facilitate information sharing and cooperation across industries. To build a culture of safety and improve public awareness, RISC-KIT will target and involve regional end-users through information exchange and summer schools

- PfA4: Reduce the underlying risk factors; RISC-KIT recognizes that sustainable ecosystems and environmental management are key ingredients in designing cost-effective DRR plans.

- PfA5: Strengthen disaster preparedness for effective response at all levels; Through dissemination to end users and stakeholders, RISC-KIT increases capacity building on coastal risk management and contribute to risk reduction at policy, technical and institutional levels.

### 4.2 Design of cost-effective risk-reduction plans, based on the proposed tools and solutions.

Coastal managers will be able to assess coastal risk at the regional (administrative) scale and identify hot spot (priority) areas for which detailed EWS can be implemented and innovative, cost-effective and ecosystem-based DRR plans can be designed. These plans will be ‘environmentally sustainable, economically equitable, socially responsible and culturally sensitive’, combining all relevant aspects of Integrated Coastal Zone Management. Evaluation criteria will ensure that these options will strive for policy coherence and cost-effectiveness.

### 4.3 Improve risk governance and preparedness through the provision of timely information and warnings to decision-makers.

The EWS/DSS will improve risk governance and preparedness through the provision of timely information and warnings to decision-makers. In the event of an impending disaster, the EWS/DSS will allow managers to take rapid decisions based on the latest information on impacts. The CRAF and the scenario evaluation tool will help decrease the ex-ante coastal risk by providing policy makers with information on vulnerable hot spots. Through on-going end-user interaction, RISC-KIT will foster information exchange between disaster managers and technical developers.

## 5 Acknowledgements

The work described in this publication was supported by the European Community's 7th Framework Programme through the grant to the budget of RISC-KIT, contract no. 603458, and by contributions by the partner institutes.

## References

1. Bates, P.D., Matthew S. Horritt, Timothy J. Fewtrell, A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling, *Journal of Hydrology*, Volume 387, Issues 1–2, 7 June 2010, Pages 33–45, ISSN 0022-1694, <http://dx.doi.org/10.1016/j.jhydrol.2010.03.027>.
2. Booij, N., R.C. Ris and L.H. Holthuijsen. 1999. A third generation wave model for coastal regions, Part

- I, Model description and validation, *J. Geophys. Res.*, 104, C4, 7649-7666.
3. Galland, J.C.; Goutal, N.; Hervouet, J.M. (1991), "TELEMAC: A New Numerical Model for Solving Shallow Water Equations", *Advances in Water Resources AWREDI* 14 (3): 138–148, doi:10.1016/0309-1708(91)90006-A
  4. Lesser, G.R., Roelvink, J.A., van Kester, J.A.T.M., Stelling, G.S., 2004. Development and validation of a three dimensional morphological model. *Journal of Coastal Engineering*, 51, 883-915.
  5. Poelhekke, L., W.S. Jäger, T.A. Plomaritis, A.R. Van Dongeren, R.T. McCall, O. Ferreira (2016). Estimating Coastal Hazards for Sandy Coastlines with a Bayesian Network, *Coastal Engineering*, in prep.
  6. Roelvink, J.A., A. Reniers, A. Van Dongeren, J. Van Thiel de Vries, R. McCall, J. Lescinski. 2009. Modeling storm impacts on beaches, dunes and barrier islands. *Coastal Engineering*, doi: 10.1016/j.coastaleng.2009.08.006
  7. Tolman, H., (2009): User manual and system documentation of WAVEWATCH III™ version 3.14. NOAA / NWS / NCEP / MMAB Technical Note 276, 194 pp + Appendices.
  8. Van Dongeren, A., Ciavola, P., Viavattene, C., De Kleermaeker, S., Martinez, G., Ferreira, O., Costa C. and R. McCall, 2014. RISC-KIT: Resilience-Increasing Strategies for Coasts – toolkit. In: Green, A.N. and Cooper, J.A.G. (eds.), *Proceedings 13th International Coastal Symposium (Durban, South Africa)*, *Journal of Coastal Research*, Special Issue No. 66, ISSN 0749-0208.
  9. Viavattene, C., J.A Jimenez, O. Ferreira, A. Bolle, D. Owen, S. Priest, A. van Dongeren (2016). A Coastal Risk Assessment Framework tool to identify hotspots at the regional scale. *Ocean Sciences*, Poster EC34B-1179, New Orleans.
  10. Zhang, Y.-L. and Baptista, A.M. (2008) SELFIE: A semi-implicit Eulerian-Lagrangian finite-element model for cross-scale ocean circulation. *Ocean Modelling*, 21(3-4), 71-96.